

# **ARKANSAS**

## **K-12 SCIENCE STANDARDS**

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EDUCATION FOR A NEW GENERATION

### **Physics**

**2016**

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### Notes:

1. Student Performance Expectations (PEs) may be taught in any sequence or grouping within a grade level. Several PEs are described as being “partially addressed in this course” because the same PE is revisited in a subsequent course during which that PE is fully addressed.
2. An asterisk (\*) indicates an engineering connection to a practice, core idea, or crosscutting concept.
3. The Performance Expectation codes ending in AR indicate Arkansas-specific standards.
4. The Clarification Statements are examples and additional guidance for the instructor. **AR** indicates Arkansas-specific Clarification Statements.
5. The Assessment Boundaries delineate content that may be taught but not assessed in large-scale assessments. **AR** indicates Arkansas-specific Assessment Boundaries.
6. The section entitled “foundation boxes” is reproduced verbatim from *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Integrated and reprinted with permission from the National Academy of Sciences.
7. The examples given (e.g.,) are suggestions for the instructor.
8. Throughout this document, connections are provided to the nature of science as defined by *A Framework for K-12 Science Education* (NRC 2012).
9. Throughout this document, connections are provided to Engineering, Technology, and Applications of Science as defined by *A Framework for K-12 Science Education* (NRC 2012).
10. Each set of PEs lists connections to other disciplinary core ideas (DCIs) within the Arkansas K-12 Science Standards and to the Arkansas English Language Arts Standards, Arkansas Disciplinary Literacy Standards, and the Arkansas Mathematics Standards.

## Arkansas K-12 Science Standards Overview

The Arkansas K-12 Science Standards are based on *A Framework for K-12 Science Education* (NRC 2012) and are meant to reflect a new vision for science education. The following conceptual shifts reflect what is new about these science standards. The Arkansas K-12 Science Standards

- reflect science as it is practiced and experienced in the real world,
- build logically from Kindergarten through Grade 12,
- focus on deeper understanding as well as application of content,
- integrate practices, crosscutting concepts, and core ideas, and
- make explicit connections to literacy and math.

As part of teaching the Arkansas K-12 Science Standards, it will be important to instruct and guide students in adopting appropriate safety precautions for their student-directed science investigations. Reducing risk and preventing accidents in science classrooms begin with planning. The following four steps are recommended in carrying out a hazard and risk assessment for any planned lab investigation:

- 1) Identify all hazards. Hazards may be physical, chemical, health, or environmental.
- 2) Evaluate the type of risk associated with each hazard.
- 3) Write the procedure and all necessary safety precautions in such a way as to eliminate or reduce the risk associated with each hazard.
- 4) Prepare for any emergency that might arise in spite of all of the required safety precautions.

According to Arkansas Code Annotated § 6-10-113 (2012) for eye protection, every student and teacher in public schools participating in any chemical or combined chemical-physical laboratories involving caustic or explosive chemicals or hot liquids or solids is required to wear industrial-quality eye protective devices (eye goggles) at all times while participating in science investigations.

The Arkansas K-12 Science Standards outline the knowledge and science and engineering practices that all students should learn by the end of high school. The standards are three-dimensional because each student performance expectation engages students at the nexus of the following three dimensions:

- Dimension 1 describes scientific and engineering practices.
- Dimension 2 describes crosscutting concepts, overarching science concepts that apply across science disciplines.
- Dimension 3 describes core ideas in the science disciplines.

### Science and Engineering Practices

The eight practices describe what scientists use to investigate and build models and theories of the world around them or that engineers use as they build and design systems. The practices are essential for all students to learn and are as follows:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

## Crosscutting Concepts

The seven crosscutting concepts bridge disciplinary boundaries and unit core ideas throughout the fields of science and engineering. Their purpose is to help students deepen their understanding of the disciplinary core ideas, and develop a coherent, and scientifically based view of the world. The seven crosscutting concepts are as follows:

1. *Patterns*- Observed patterns of forms and events guide organization and classification, and prompt questions about relationships and the factors that influence them.
2. *Cause and effect- Mechanism and explanation*. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.
3. *Scale, proportion, and quantity*- In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.
4. *Systems and system models*- Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.
5. *Energy and matter: Flows, cycles, and conservation*- Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.
6. *Structure and function*- The way in which an object or living thing is shaped and its substructure determines many of its properties and functions.
7. *Stability and change*- For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

## Disciplinary Core Ideas

The disciplinary core ideas describe the content that occurs at each grade or course. The Arkansas K-12 Science Standards focus on a limited number of core ideas in science and engineering both within and across the disciplines and are built on the notion of learning as a developmental progression. The Disciplinary Core Ideas are grouped into the following domains:

- Physical Science (PS)
- Life Science (LS)
- Earth and Space Science (ESS)
- Engineering, Technology and Applications of Science (ETS)

## Connections to the Arkansas English Language Arts Standards

Evidence-based reasoning is the foundation of good scientific practice. The Arkansas K-12 Science Standards incorporate reasoning skills used in language arts to help students improve mastery and understanding in all three disciplines. The Arkansas K-8 Science Committee made every effort to align grade-by-grade with the English language arts (ELA) standards so concepts support what students are learning in their entire curriculum. Connections to specific ELA standards are listed for each student performance expectation, giving teachers a blueprint for building comprehensive cross-disciplinary lessons.

The intersections between Arkansas K-12 Science Standards and Arkansas ELA Standards teach students to analyze data, model concepts, and strategically use tools through productive talk and shared activity. Reading in science requires an appreciation of the norms and conventions of the discipline of

science, including understanding the nature of evidence used, an attention to precision and detail, and the capacity to make and assess intricate arguments, synthesize complex information, and follow detailed procedures and accounts of events and concepts. These practice-based standards help teachers foster a classroom culture where students think and reason together, connecting around the subject matter and core ideas.

### Connections to the Arkansas Disciplinary Literacy Standards

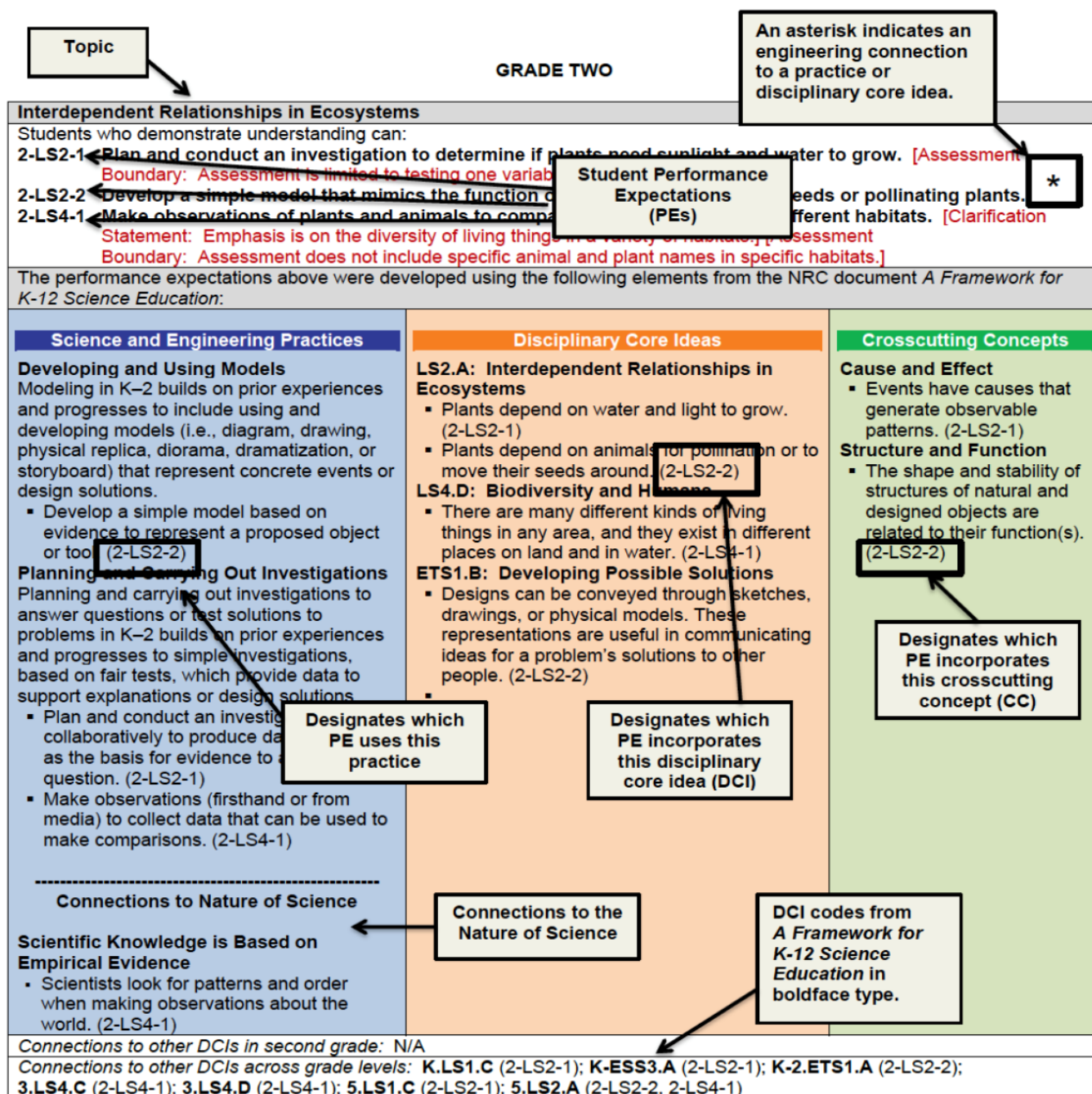
Reading is critical to building knowledge in science. College and career ready reading in science requires an appreciation of the norms and conventions of each discipline, such as the kinds of evidence used in science; an understanding of domain-specific words and phrases; an attention to precise details; and the capacity to evaluate intricate arguments, synthesize complex information, and follow detailed descriptions of events and concepts. When reading scientific and technical texts, students need to be able to gain knowledge from challenging texts that often make extensive use of elaborate diagrams and data to convey information and illustrate concepts. Students must be able to read complex informational texts in science with independence and confidence because the vast majority of reading in college and workforce training programs will be sophisticated nonfiction.

For students, writing is a key means of asserting and defending claims, showing what they know about science, and conveying what they have experienced, imagined, thought, and felt. To be college and career ready writers, students must take task, purpose, and audience into careful consideration, choosing words, information, structures, and formats deliberately. They need to be able to use technology strategically when creating, refining, and collaborating on writing. They have to become adept at gathering information, evaluating sources, and citing material accurately, reporting finds from their research and analysis of sources in a clear and cogent manner. They must have the flexibility, concentration, and fluency to produce high-quality first-draft text under a tight deadline and the capacity to revisit and make improvements to a piece of writing over multiple drafts when circumstances encourage or require it.

### Connections to the Arkansas Mathematics Standards

Science is a quantitative discipline, so it is important for educators to ensure that students' science learning coheres well with their understanding of mathematics. To achieve this alignment, the Arkansas K-12 Science Committee made every effort to ensure that the mathematics standards do not outpace or misalign to the grade-by-grade science standards. Connections to specific math standards are listed for each student performance expectation, giving teachers a blueprint for building comprehensive cross-disciplinary lessons.

# How to Read Arkansas K-12 Science



Connections to the Arkansas English Language Arts and Mathematics Standards are often found by scrolling to the next page

## Physics Learning Progression Chart

Topic 1: Motion	Topic 2: Work and Energy	Topic 3: Heat and Thermodynamics	Topic 4: Waves, Sound, and Simple Harmonic Motion	Topic 5: Electricity
P-PS1-1AR	P-PS2-1AR	AR P-PS3-1	P-PS4-1AR	AR P-PS2-4
P-PS1-2AR	P-PS2-2AR	P-PS3-1AR	P-PS4-2AR	AR P-PS2-5
AR P-PS2-1	P-PS2-3AR	P-PS3-2AR	P-PS4-3AR	AR P-PS3-2
AR P-PS2-2	P-PS2-4AR	P-PS3-3AR	AR P4-ETS1-4	P-PS5-1AR
AR P-ESS1-2	P-PS2-5AR	AR P-PS3-3		P-PS5-2AR
AR P-ESS1-4	P-PS2-6AR	AR P-PS3-4		P-PS5-3AR
AR P1-ETS1-2	AR P2-ETS1-3	AR P3-ETS1-1		AR P5-ETS1-1
		AR P3-ETS1-2		
		AR P3-ETS1-3		
		AR P3-ETS1-4		

Arkansas Clarification Statements (AR)  
Arkansas Performance Expectations (AR)

## Physics Course Overview

(Course code 422010)

Physics is a science course that builds upon students' understanding of the core ideas, science and engineering practices, and crosscutting concepts in the chemistry - integrated course. The standards engage students in the investigation of physical laws and application of the principles of physics to address real world problems. Candidates for this course are students who have completed chemistry-integrated and are seeking a deeper understanding of physics concepts. It is recommended that students have completed or are concurrently enrolled in an algebra II course. Students will earn 1 unit of career focus credit. Teachers with a physics, physical/earth, physics/math license or others as approved by ADE are able to teach this course.

There are seven topics in physics: 1) Motion, (2) Work and Energy, (3) Heat and Thermodynamics, (4) Waves, Sound, and Simple Harmonic Motion, and 5) Electricity.

It should be noted that the physics standards are not intended to be used as curriculum. Instead, the standards are the minimum that students should know and be able to do. Therefore, teachers should continue to differentiate for the needs of their students by adding depth and additional rigor.

Students in physics continue to develop possible solutions for major global problems with engineering design challenges. At the high school level, students are expected to engage with major global issues at the interface of science, technology, society and the environment, and to bring to light the kinds of analytical and strategic thinking that prior training and increased maturity make possible. As in prior levels, these capabilities can be thought of in three stages:

- **Defining the problem** at the high school level requires both qualitative and quantitative analysis. For example, the need to provide food and fresh water for future generations comes into sharp focus when considering the speed at which the world population is growing and conditions in countries that have experienced famine. While high school students are not expected to solve these challenges, they are expected to begin thinking about them as problems that can be addressed, at least in part, through engineering.
- **Developing possible solutions** for major global problems begins by breaking them down into smaller problems that can be tackled with engineering methods. To evaluate potential solutions, students are expected to not only consider a wide range of criteria but to also recognize that criteria needs to be prioritized. For example, public safety or environmental protection may be more important than cost or even functionality. Decisions on priorities can then guide tradeoff choices.
- **Improving designs** at the high school level may involve sophisticated methods, such as using computer simulations to model proposed solutions. Students are expected to use such methods to take into account a range of criteria and constraints, anticipate possible societal and environmental impacts, and test the validity of their simulations by comparison to the real world.



## Physics Topics Overview

The performance expectations in **Topic 1: Motion** help students investigate:

- Vectors
- 1-D Motion
- 2-D Motion
- Rotational Motion
- Projectile Motion
- Newton's Law of Gravity

Students investigate concepts of motion and create models, including algebraic expressions and conceptual models.

The performance expectations in **Topic 2: Work and Energy** help students investigate:

- Conservation of Energy
- Work
- Energy
- Power
- Impulse

Students conduct investigations and use mathematical models to evaluate kinetic and potential energy of systems.

The performance expectations in **Topic 3: Heat and Thermodynamics** help students investigate:

- Kinetic Molecular Theory
- Law of Thermodynamics
- Pressure
- Fluid Dynamics

Students use computational models to investigate the conservation of energy and the total change of energy in a system.

The performance expectations in **Topic 4: Waves, Sound and Simple Harmonic Motion** help students investigate:

- Longitudinal/Transverse
- Light
- Optics

Students use data to analyze wave properties and create visual and mathematical representations for the propagation of light and sound. Students use principles of simple harmonic motion to relate periodic properties of waves to vibrations. The differences and similarities of mechanical waves and electromagnetic waves are investigated through experiments involving light and sound.

The performance expectations in **Topic 5: Electricity** help students investigate:

- Potential Difference
- DC Circuits
- Power Laws
- Current and Voltage
- Transmission of Electricity
- Magnetism
- Static Charge
- Safety

Students analyze data related to the interaction of electric and magnetic fields. By creating circuits and measuring electrical quantities, students investigate fundamental laws governing electricity and magnetism. Students use Ohm's law and the power law to analyze aspects of electrical circuits.

## Physics

### Topic 1: Motion

Students who demonstrate understanding can:

- P-PS1-1AR** Create a model of motion and forces, including vectors graphed on the coordinate plane, to describe and predict the behavior of a system. [Clarification Statement: Emphasis is on vector addition for 1-D (frame of reference), 2-D motion (projectile, rotational motion), vectors applied to force diagrams, and vector direction for gravitational forces.]
- P-PS1-2AR** Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electrical fields.]
- P-PS2-1** Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. [AR Clarification Statement: Examples of data could include tables and graphs of position or velocity as functions of time for objects subject to a net unbalanced force (falling object, object rolling down a ramp, moving object being pulled by a constant force.)]
- P-PS2-2** Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object. [AR Clarification Statement: Emphasis is on balanced and unbalanced forces (Newton's first law) in a system, qualitative and quantitative comparisons of forces, mass and changes in motion (Newton's second law), frame of reference, and specification of units.] [Assessment Boundary: Assessment includes use of trigonometry.]
- P-ESS1-2** Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system. [AR Clarification Statement: Emphasis is on gravity as the force that holds the solar system and Milky Way galaxy together and controls orbital motions within them. Examples of models could be physical (analogy of distance along a football field, computer simulations of elliptical orbits) or conceptual (mathematical proportions relative to size of familiar objects).]
- P-ESS1-4** Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. [AR Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions as they apply to human-made satellites, planets, and moons.]
- P1-ETS1-2** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. [AR Clarification Statement: Problems could include acceleration factors (one-dimensional motion), vectors (two-dimensional motion), and gravity (Newton's laws).]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<b>Developing and Using Models</b> Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. <ul style="list-style-type: none"> <li>Use a model to predict the relationships between systems or between components of a system. (P-PS1-1AR, P-ESS1-2)</li> </ul>	<b>PS2.A: Forces and Motion</b> <ul style="list-style-type: none"> <li>Newton's second law accurately predicts changes in the motion of macroscopic objects. (P-PS2-1, P-PS2-2, P-PS-1-1AR, P-ESS1-2, P-ESS1-4, P1-ETS1-2)</li> </ul> <b>PS2.B: Types of Interactions</b> <ul style="list-style-type: none"> <li>Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and</li> </ul>	<b>Patterns</b> <ul style="list-style-type: none"> <li>Empirical evidence is needed to identify patterns. (P-ESS1-4)</li> <li>Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (P-ESS1-2 P-ESS1-4)</li> </ul>

## **Planning and Carrying Out Investigations**

Planning and carrying out investigations in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (P-PS2-2)

## **Using Mathematics and Computational Thinking**

Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical representations of phenomena to support claims. (P-PS1-2AR, P-ESS1-4)

## **Constructing Explanations and Designing Solutions**

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with

electrostatic forces between distant objects. (P-PS1-2AR, P-ESS1-2)

## **ETS1.C: Optimizing the Design Solution**

- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (P1-ETS1-2)

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## **Cause and Effect**

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (P-PS1-2AR, P-PS2-2, P-ESS1-2)
- Systems can be designed to cause a desired effect. (P-PS1-2AR, P-PS2-2, P-ESS1-2)

## **Systems and System Models**

- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (P-PS1-1AR)
- Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. (P-PS1-1AR)

## **Structure and Function**

- Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (P-PS2-1)

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## **Connections to Nature of Science**

## **Scientific Knowledge Assumes an Order and Consistency in Natural Systems**

- Science assumes the universe is a vast single system in which basic laws

<p>scientific ideas, principles, and theories.</p> <ul style="list-style-type: none"> <li>Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (P1-ETS1-2)</li> </ul> <p>Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (P1-ETS1-2)</p> <ul style="list-style-type: none"> <li>Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.</li> <li>(P1-ETS1-2)</li> </ul> <p><b>Analyzing and Interpreting Data</b></p> <p>Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.</p> <ul style="list-style-type: none"> <li>Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (P-PS2-1)</li> <li>Analyze data using computational models in order to make valid and reliable scientific claims. (P-PS2-1)</li> </ul>		<p>are consistent. (P-PS1-2AR, P-ESS1-2 )</p> <ul style="list-style-type: none"> <li>Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. (P-PS1-2AR, P-ESS1-2 )</li> </ul> <p>-----</p> <p><b><i>Connections to Engineering, Technology, and Applications of Science</i></b></p> <p><b>Interdependence of Science, Engineering, and Technology</b></p> <ul style="list-style-type: none"> <li>Science and engineering complement each other in the cycle known as research and development (R&amp;D). Many R&amp;D projects may involve scientists, engineers, and others with wide ranges of expertise. (P1-ETS1-2)</li> </ul> <p><b>Influence of Engineering, Technology, and Science on Society and the Natural World</b></p> <ul style="list-style-type: none"> <li>Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (P1-ETS1-2)</li> <li>New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (P1-ETS1-2)</li> </ul>
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*Connections to the Arkansas Disciplinary Literacy Standards:*

- RST.9-10.7** Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. (P-PS1-2AR, P-ESS1-4)
- RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (P-PS2-1, P-ESS1-2)
- RST.11-12.7** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (P-PS2-1)
- RST.11-12.8** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (P-PS2-2)
- WHST.9-12.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (P-PS2-2, P-ESS1-2)
- WHST.9-12.9** Draw evidence from informational texts to support analysis, reflection, and research. (P-PS2-1)

*Connections to the Arkansas English Language Arts Standards:*

- SL.11-12.2** Integrate multiple sources of information that is gained by means other than reading (e.g., texts read aloud; oral presentations of charts, graphs, diagrams; speeches) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data. (P1-ETS1-2)

*Connections to the Arkansas Mathematics Standards:*

- MP.2** Reason abstractly and quantitatively. (P-PS2-1, P-PS2-2, P-ESS1-2, P-ESS1-4, P1-ETS1-2)
- MP.4** Model with mathematics. (P-PS2-1, P-PS2-2, P-ESS1-4)
- HSN.Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (P-PS2-1, P-PS2-2, P-ESS1-2, P-ESS1-4)
- HSN.Q.A.2** Define appropriate quantities for the purpose of descriptive modeling. (P-PS2-1, P-PS2-2, P-ESS1-2, P-ESS1-4)
- HSN.Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (P-PS2-1, P-PS2-2, P-ESS1-2)
- HSN.VM.A.1** Recognize vector quantities as having both magnitude and direction; represent vector quantities by directed line segments, and use appropriate symbols for vectors and their magnitudes. (P-PS1-1, P-PS2-1)
- HSN.VM.A.3** Solve problems involving velocity and other quantities that can be represented by vectors. (P-PS1-1, P-PS2-1, P1-ETS1-2)
- HSN.VM.B.4** Add and subtract vectors: add vectors end-to-end, compound-wise, and by the parallelogram rule. Understand that the magnitude of a sum of two vectors is typically not the sum of the magnitudes; given two vectors in magnitude and direction form, determine the magnitude and direction of their sum; understand vector subtraction  $\mathbf{v} - \mathbf{w}$  as  $\mathbf{v} + (-\mathbf{w})$ , where  $-\mathbf{w}$  is the additive inverse of  $\mathbf{w}$ , with the same magnitude as  $\mathbf{w}$  and pointing in the opposite direction; represent vector subtraction graphically by connecting the tips in the appropriate order; perform vector subtraction component-wise. (P-PS1-1)
- HSA.SSE.A.1** Interpret expressions that represent a quantity in terms of its context. (P-PS2-1 P-ESS1-2, P-ESS1-4)
- HSA.SSE.B.3** Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (P-PS2-1)

<b>HSA.CED.A.1</b>	Create equations and inequalities in one variable and use them to solve problems. (P-PS1-2AR, P-PS2-1, P-PS2-2)
<b>HSA.CED.A.2</b>	Create equations in two or more variables to represent relationships between quantities; graph equations, in two variables, on a coordinate plane. (P-PS2-1, P-PS2-2, P-ESS1-2, P-ESS1-4)
<b>HSA.CED.A.4</b>	Rearrange literal equations using the properties of equality. (P-PS1-2AR, P-PS2-1, P-PS2-2, P-ESS1-2, P-ESS1-4)
<b>HSF.IF.C.7</b>	Graph functions expressed algebraically and show key features of the graph, with and without technology: graph linear and quadratic functions and, when applicable, show intercepts, maxima, and minima; graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions; graph polynomial functions, identifying zeros when suitable factorizations are available, and showing end behavior; graph rational functions, identifying zeros and asymptotes when suitable factorizations are available, and showing end behavior; graph exponential and logarithmic functions, showing intercepts and end behavior; graph trigonometric functions, showing period, midline, and amplitude. (P-PS2-1)
<b>HSG.SRT.A.2</b>	Given two figures: use the definition of similarity in terms of similarity transformations to determine if they are similar; explain using similarity transformations the meaning of similarity for triangles as the equality of all corresponding pairs of angles and the proportionality of all corresponding pairs of sides. (P-ESS1-2)
<b>HSG.SRT.C.8</b>	Use trigonometric ratios, special right triangles, and the Pythagorean Theorem to find unknown measurements of right triangles in applied problems. (P-PS2-2)
<b>HSG.MG.A.1</b>	Use geometric shapes, their measures, and their properties to describe objects. (P-ESS1-4)
<b>HSS.ID.A.1</b>	Represent data with plots on the real number line. (P-PS2-1)



## Physics

Topic 2: Work and Energy		
Students who demonstrate understanding can:		
P-PS2-1AR	Develop computational and graphical models to calculate and illustrate the work done and changes in energy in a system. [Clarification Statement: Emphasis is on force vs. displacement graph.]	
P-PS2-2AR	Plan and conduct an investigation to provide evidence that work done equals energy stored in a conservative system. [Clarification Statement: An example of an investigation could include Hooke’s law where energy is stored in a spring.]	
P-PS2-3AR	Plan and conduct an investigation to rate the power used in performing work on a system. [Clarification Statement: Emphasis is on the quantitative determination of power in interactions. Examples could include use of pulleys and electric motors.]	
P-PS2-4AR	Analyze data to demonstrate the relationship between rotational and linear motion, energy, and momentum. [Clarification Statement: Emphasis is on linear motion and angular motion, force and torque, linear momentum and angular momentum, and linear kinetic energy and rotational kinetic energy, mass and moment of inertia.]	
P-PS2-5AR	Use mathematical representations to support the claim that the change in kinetic energy of a system is equal to the net work performed upon the system. [Clarification Statement: Emphasis is on quantitative kinetic energy in interactions.]	
P-PS2-6AR	Use mathematical representations to support the claim that the total impulse on a system of objects is equal to the change in momentum of the system. [Clarification Statement: Emphasis is on quantitative conservation of momentum in interactions.]	
P2-ETS1-3	Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. [AR Clarification Statement: Examples could include analysis of nuclear, coal, and hydro-electric power plants.]	
The performance expectations above were developed using the following elements from the NRC document <i>A Framework for K-12 Science Education</i> :		
<b>Science and Engineering Practices</b> <b>Developing and Using Models</b> Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). <ul style="list-style-type: none"><li>Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (P-PS2-1AR)</li></ul> <b>Constructing Explanations and Designing Solutions</b> Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and	<b>Disciplinary Core Ideas</b> <b>PS2.A: Forces and Motion</b> <ul style="list-style-type: none"><li>Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (P-PS2-6AR)</li><li>In any system, total momentum is always conserved. If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. (P-PS2-6AR)</li></ul> <b>PS3.A: Definitions of Energy</b> <ul style="list-style-type: none"><li>Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity</li></ul>	<b>Crosscutting Concepts</b> <b>Energy and Matter</b> <ul style="list-style-type: none"><li>The total amount of energy and matter in closed systems is conserved. (P-PS2-4AR, P-PS2-5AR)</li><li>Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (P-PS2-4AR, P-PS2-5AR)</li><li>Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (P-PS2-4AR, P-PS2-5AR)</li></ul>



independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

- Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. (P2-ETS1-3)
- Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (P2-ETS1-3)
- Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (P2-ETS1-3)

### Using Mathematics and Computational Thinking

Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (P-PS2-5AR, P-PS2-6AR)

### Planning and Carrying Out Investigations

Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (P-PS2-2AR)

### PS3.B: Conservation of Energy and Energy Transfer

- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (P-PS2-2AR)
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (P-PS2-2AR)

### PS3.C: Relationship Between Energy and Forces

- When two objects interacting through a force field change relative position, the energy stored in the force field is changed. (P-PS2-1AR, P-PS2-3AR, P-PS2-5AR)

### PS3.D: Energy in Chemical Processes

- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. Machines are judged as efficient or inefficient based on the amount of energy input needed to perform a particular useful task. Inefficient machines are those that produce more waste heat while performing a task and thus require more energy

### Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (P-PS2-6AR)
- Systems can be designed to cause a desired effect. (P-PS2-6AR)

### Systems and System Models

- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (P-PS2-1AR, P-PS2-2AR, P-PS2-3AR)
- Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. (P-PS2-1AR, P-PS2-2AR, P-PS2-3AR)

### Connections to Engineering, Technology, and Applications of Science

### Influence of Science, Engineering, and Technology on Society and the Natural World

- Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (P2-ETS1-3)
- New technologies can have deep impacts on society and

<ul style="list-style-type: none"> <li>Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (P-PS2-2AR, P-PS2-3AR)</li> </ul> <p><b>Analyzing and Interpreting Data</b> Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.</p> <ul style="list-style-type: none"> <li>Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (P-PS2-4AR)</li> </ul> <hr/> <p><b>Connections to Nature of Science</b></p> <p><b>Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena</b></p> <ul style="list-style-type: none"> <li>A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (P-PS2-2AR, P-PS2-3AR)</li> <li>Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory. (P-PS2-2AR, P-PS2-3AR)</li> </ul>	<p>input. It is therefore important to design for high efficiency so as to reduce costs, waste materials, and many environmental impacts. (P2-ETS1-3)</p> <p><b>ETS1.A: Defining and Delimiting Engineering Problems</b> Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (P2-ETS1-3)</p> <ul style="list-style-type: none"> <li>Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (P2-ETS1-3)</li> </ul> <p><b>ETS1.B: Developing Possible Solutions</b></p> <ul style="list-style-type: none"> <li>When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (P2-ETS1-3)</li> <li>Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (P2-ETS1-3)</li> </ul> <p><b>ETS1.C: Optimizing the Design Solution</b></p> <ul style="list-style-type: none"> <li>Criteria may need to be broken down into simpler ones that can</li> </ul>	<p>the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (P2-ETS1-3)</p> <hr/> <p><b>Connections to Nature of Science</b></p> <p><b>Scientific Knowledge Assumes an Order and Consistency in Natural Systems</b></p> <ul style="list-style-type: none"> <li>Science assumes the universe is a vast single system in which basic laws are consistent. (P-PS2-1AR, P-PS2-2AR, P-PS2-3AR)</li> </ul>
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	be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (P2-ETS1-3)	
<i>Connections to the Arkansas Disciplinary Literacy Standards:</i>		
<b>RST.9-10.7</b>	Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. (P-PS2-4AR)	
<b>RST.11-12.7</b>	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (P2-ETS1-3)	
<b>RST.11-12.8</b>	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (P-PS2-2AR, P-PS2-3AR, P2-ETS1-3)	
<b>RST.11-12.9</b>	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (P2-ETS1-3)	
<b>WHST.9-12.2</b>	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (P-PS2-2AR, P-PS2-3AR)	
<b>WHST.11-12.8</b>	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (P2-ETS1-3)	
<i>Connections to the Arkansas English Language Arts Standards:</i>		
<b>SL.11-12.2</b>	Integrate multiple sources of information that is gained by means other than reading (e.g., texts read aloud; oral presentations of charts, graphs, diagrams; speeches) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data. (P-PS2-1AR, P2-ETS1-3)	
<b>SL.11-12.4</b>	Present information, findings, and supporting evidence, conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks. (P-PS2-2AR, P-PS2-3AR, P-PS2-5AR, P-PS2-6AR)	
<i>Connections to the Arkansas Mathematics Standards:</i>		
<b>MP.2</b>	Reason abstractly and quantitatively. (P-PS2-1AR, P-PS2-2AR, P-PS2-3AR, P-PS2-4AR, P-PS2-5AR, P-PS2-6AR, P2-ETS1-3)	
<b>MP.4</b>	Model with mathematics. (P-PS2-1AR, P-PS2-2AR, P-PS2-3AR, P-PS2-4AR, P-PS2-5AR, P-PS2-6AR, P2-ETS1-3)	
<b>HSN.Q.A.1</b>	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (P-PS2-1AR, P-PS2-2AR, P-PS2-3AR, P-PS2-4AR, P-PS2-5AR, P-PS2-6AR, P2-ETS1-3)	
<b>HSN.Q.A.2</b>	Define appropriate quantities for the purpose of descriptive modeling. (P-PS2-1AR P-PS2-2AR, P-PS2-3AR, P-PS2-4AR, P-PS2-5AR, P-PS2-6AR, P2-ETS1-3)	
<b>HSN.Q.A.3</b>	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (P-PS2-1AR P-PS2-2AR, P-PS2-3AR, P-PS2-4AR, P-PS2-5AR, P-PS2-6AR, P2-ETS1-3)	

<b>HSF.IF.C.7</b>	Graph functions expressed algebraically and show key features of the graph, with and without technology: graph linear and quadratic functions and, when applicable, show intercepts, maxima, and minima; graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions; graph polynomial functions, identifying zeros when suitable factorizations are available, and showing end behavior; graph rational functions, identifying zeros and asymptotes when suitable factorizations are available, and showing end behavior; graph exponential and logarithmic functions, showing intercepts and end behavior; graph trigonometric functions, showing period, midline, and amplitude. (P-PS2-4AR, P-PS2-5AR, P-PS2-6AR)
<b>HSS.ID.A.1</b>	Represent data with plots on the real number line. (P-PS2-1AR)

## Physics

### Topic 3: Heat and Thermodynamics

Students who demonstrate understanding can:

- P-PS3-1** Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. [AR Clarification Statement: Emphasis is on systems of two or three components, thermal energy, kinetic energy, and energies in gravitational, magnetic, and electric fields.]
- P-PS3-1AR** Construct an explanation based on evidence of the relationships between heat, temperature, and the Kinetic Molecular Theory. [Clarification Statement: Emphasis on planning and conducting experiments to collect then analyze data. An example could include measuring temperature changes related to phase change and specific heat.]
- P-PS3-2AR** Plan and conduct an investigation of the relationships between pressure, volume, temperature, and amount of gas. [Clarification Statement: Emphasis is on use of gas law apparatuses.]
- P-PS3-3AR** Use mathematical representations to model the conservation of energy in fluids. [Clarification Statement: Emphasis is on fluid dynamics as expressed in Bernoulli's equation and Pascal's principle.]
- P-PS3-3** Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.\* [AR Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.]
- P-PS3-4** Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics). [AR Clarification Statement: Emphasis is on mathematical thinking to describe energy changes. Examples of investigations could include mixing liquids at different initial temperatures and adding objects at different temperatures to water.]
- P3-ETS1-1** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. [AR Clarification Statement: Examples could include use of wind and solar energy and total energy loss from homes.]
- P3-ETS1-2** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. [AR Clarification Statement: Examples could include designing and building a machine, using schematics to break down an engine into major functional blocks, and designing improvements to reduce total energy loss from a home.]
- P3-ETS1-3** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. [AR Clarification Statement: Examples could include evaluating the different parts of a machine, the entire machine, and reducing energy loss in homes.]
- P3-ETS1-4** Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem. [AR Clarification Statement: Examples could include analyzing potential and kinetic energy efficiency (windmills, roller coasters) and modeling energy loss in homes with and without proposed improvements.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:



Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<p><b>Developing and Using Models</b> Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).</p> <ul style="list-style-type: none"> <li>Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (P-PS3-1, P-ETS1-4)</li> </ul> <p><b>Constructing Explanations and Designing Solutions</b> Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.</p> <ul style="list-style-type: none"> <li>Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. (P-PS3-1AR, P-PS3-3, P-ETS1-2)</li> <li>Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (P-PS3-1AR, P-PS3-3, P-ETS1-2)</li> <li>Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (P-PS3-1AR, P-PS3-3, P-ETS1-2)</li> </ul> <p><b>Using Mathematics and Computational Thinking</b> Mathematical and computational thinking in 9–12 builds on K–8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions,</p>	<p><b>PS2.C: Stability and Instability in Physical Systems</b></p> <ul style="list-style-type: none"> <li>Systems often change in predictable ways; understanding the forces that drive the transformations and cycles within a system, as well as the forces imposed on the system from the outside, helps predict its behavior under a variety of conditions. (P-PS3-4)</li> <li>When a system has a great number of component pieces, one may not be able to predict much about its precise future. For such systems (e.g., with very many colliding molecules), one can often predict average but not detailed properties and behaviors (e.g., average temperature, motion, and rates of chemical change but not the trajectories or other changes of particular molecules). (P-PS3-4, P-PS3-1AR, P-PS3-2)</li> </ul> <p><b>PS3.A: Definitions of Energy</b></p> <ul style="list-style-type: none"> <li>Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (P-PS3-1)</li> </ul> <p><b>PS3.B: Conservation of Energy and Energy Transfer</b></p> <ul style="list-style-type: none"> <li>Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.</li> </ul>	<p><b>Energy and Matter</b></p> <ul style="list-style-type: none"> <li>The total amount of energy and matter in closed systems is conserved. (P-PS3-3, P-PS3-4, P-PS3-3AR)</li> <li>Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (P-PS3-3, P-PS3-4, P-PS3-3AR)</li> <li>Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (P-PS3-3, P-PS3-4, P-PS3-3AR)</li> </ul> <p><b>Cause and Effect</b></p> <ul style="list-style-type: none"> <li>Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (P-PS3-1, P-PS3-1AR, P-PS3-2AR)</li> <li>Systems can be designed to cause a desired effect. (P-PS3-1, P-PS3-1AR, P-PS3-2AR)</li> </ul> <hr/> <p><b>Connections to Nature of Science</b></p> <p><b>Scientific Knowledge Assumes an Order and Consistency in Natural Systems</b></p> <ul style="list-style-type: none"> <li>Science assumes the universe is a vast single system in which basic laws are consistent. (P-PS3-1AR, P-PS3-2AR, P-PS3-4)</li> <li>Scientific knowledge is based on the assumption</li> </ul>

<p>exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.</p> <ul style="list-style-type: none"> <li>Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (P-PS3-3AR)</li> </ul> <p><b>Planning and Carrying Out Investigations</b></p> <p>Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.</p> <ul style="list-style-type: none"> <li>Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (P-PS3-2AR, P-PS3-4)</li> </ul> <p><b>Asking Questions and Defining Problems</b></p> <p>Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.</p> <ul style="list-style-type: none"> <li>Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (P3-ETS1-1, P3-ETS1-3)</li> </ul>	<p>(P-PS3-1AR, P-PS3-3)</p> <ul style="list-style-type: none"> <li>Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). Any object or system that can degrade with no added energy is unstable. Eventually it will do so, but if the energy releases throughout the transition are small, the process duration can be very long (e.g., long-lived radioactive isotopes). (P-PS3-4)</li> </ul> <p><b>PS3.D: Energy in Chemical Processes</b></p> <ul style="list-style-type: none"> <li>Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. Machines are judged as efficient or inefficient based on the amount of energy input needed to perform a particular useful task. Inefficient machines are those that produce more waste heat while performing a task and thus require more energy input. It is therefore important to design for high efficiency so as to reduce costs, waste materials, and many environmental impacts (P-PS3-3, P3-ETS1-1)</li> </ul> <p><b>ETS1.A: Defining and Delimiting Engineering Problems</b></p> <ul style="list-style-type: none"> <li>Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (P3-ETS1-1, P3-ETS1-3)</li> <li>Humanity faces major global challenges today, such as</li> </ul>	<p>that natural laws operate today as they did in the past and they will continue to do so in the future. (P-PS3-1AR, P-PS3-2AR, P-PS3-4)</p> <p>-----</p> <p><b><i>Connections to Engineering, Technology, and Applications of Science</i></b></p> <p><b>Interdependence of Science, Engineering, and Technology</b></p> <ul style="list-style-type: none"> <li>Science and engineering complement each other in the cycle known as research and development (R&amp;D). Many R&amp;D projects may involve scientists, engineers, and others with wide ranges of expertise. (P3-ETS1-1, P3-ETS1-2, P3-ETS1-3, P3-ETS1-4)</li> </ul> <p><b>Influence of Engineering, Technology, and Science on Society and the Natural World</b></p> <ul style="list-style-type: none"> <li>Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (P3-ETS1-1, P3-ETS1-2, P3-ETS1-3, P3-ETS1-4)</li> <li>New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (P3-ETS1-1, P3-ETS1-2, P3-ETS1-3, P3-ETS1-4)</li> </ul>
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	<p>the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (P3-ETS1-1, P3-ETS1-3)</p> <p><b>ETS1.B: Developing Possible Solutions</b></p> <ul style="list-style-type: none"> <li>When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (P3-ETS1-2, P3-ETS1-4)</li> </ul>	
<p><i>Connections to the Arkansas Disciplinary Literacy Standards:</i></p> <p><b>RST.11-12.1</b> Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (P-PS3-1AR, P-PS3-4)</p> <p><b>RST.11-12.7</b> Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (P-PS3-2AR, P3-ETS1-1)</p> <p><b>RST.11-12.8</b> Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (P-PS3-2AR, P3-ETS1-3)</p> <p><b>RST.11-12.9</b> Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (P-PS3-1AR, P-PS3-2AR, P3-ETS1-1, P3-ETS1-3)</p> <p><b>WHST.9-12.2</b> Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (P-PS3-1AR, P-PS3-2AR)</p> <p><b>WHST.9-12.7</b> Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (P-PS3-3, P-PS3-4)</p> <p><b>WHST.11-12.8</b> Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (P-PS3-1AR, P-PS3-4, P3-ETS1-1)</p> <p><i>Connections to the Arkansas English Language Arts Standards:</i></p> <p><b>SL.11-12.2</b> Integrate multiple sources of information that is gained by means other than reading (e.g., texts read aloud; oral presentations of charts, graphs, diagrams; speeches) in order to make informed</p>		



	decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data. (P-PS3-1AR)
<b>SL.11-12.4</b>	Present information, findings, and supporting evidence, conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks. (P-PS3-1AR)
<b>SL.11-12.5</b>	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (P-PS3-1, P-PS3-1AR, P-PS3-2AR)
<i>Connections to the Arkansas Mathematics Standards:</i>	
<b>MP.2</b>	Reason abstractly and quantitatively. (P-PS3-1, P-PS3-1AR, P-PS3-2AR, P-PS3-3AR, P-PS3-3, P-PS3-4, P3-ETS1-1, P3-ETS1-2, P3-ETS1-3, P3-ETS1-4)
<b>MP.4</b>	Model with mathematics. (P-PS3-1, P-PS3-1AR, P-PS3-2AR, P-PS3-3AR, P-PS3-3, P-PS3-4, P3-ETS1-1, P3-ETS1-2, P3-ETS1-3, P3-ETS1-4)
<b>HSN.Q.A.1</b>	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (P-PS3-1, P-PS3-1AR, P-PS3-2AR, P-PS3-3AR, P-PS3-3, P-PS3-4, P3-ETS1-1, P3-ETS1-2, P3-ETS1-3, P3-ETS1-4)
<b>HSN.Q.A.2</b>	Define appropriate quantities for the purpose of descriptive modeling. (P-PS3-1, P-PS3-1AR, P-PS3-2AR, P-PS3-3AR, P-PS3-3, P-PS3-4, P3-ETS1-1, P3-ETS1-2, P3-ETS1-3, P3-ETS1-4)
<b>HSN.Q.A.3</b>	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (P-PS3-1, P-PS3-1AR, P-PS3-2AR, P-PS3-3AR, P-PS3-3, P-PS3-4, P3-ETS1-1, P3-ETS1-2, P3-ETS1-3, P3-ETS1-4)
<b>HSA.CED.A.1</b>	Create equations and inequalities in one variable and use them to solve problems. (P-PS3-3)
<b>HSA.CED.A.3</b>	Represent and interpret constraints by equations or inequalities, and by systems of equations and/or inequalities. (P-PS3-3AR)
<b>HSA.CED.A.4</b>	Rearrange literal equations using the properties of equality. (P-PS3-3AR)
<b>HSS.IC.B.6</b>	Read and explain, in context, the validity of data from outside reports by: identifying the variables as quantitative or categorical; describing how the data was collected; indicating any potential biases or flaws; identifying inferences the author of the report made from sample data. (P3-ETS1-1)

## Physics

### Topic 4: Waves, Sound, and Simple Harmonic Motion

Students who demonstrate understanding can:

- P-PS4-1AR** Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, speed, and energy of waves traveling in various media. [Clarification Statement: Emphasis is on the dependence of wave speed upon media properties and the proportionality between the quantities (frequency and speed, wavelength and speed, frequency and wavelength, energy and wavelength).]
- P-PS4-2AR** Develop and use models to investigate longitudinal and transverse waves in various media. [Clarification Statement: Emphasis is on structure and function of waves.]
- P-PS4-3AR** Develop and use models to describe the interaction of light with matter. [Clarification Statement: Emphasis is on both geometric (ray diagrams) and algebraic models (mirror and thin lens equation, Snell's law).]
- P4-ETS1-4** Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem. [AR Clarification Statement: Emphasis is on solutions with various constraints and criteria. An example could include effect of wind resistance on structural integrity of a skyscraper as a function of its height.]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

#### Science and Engineering Practices

##### Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 9-12 level builds on K-8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. (P-PS4-1AR)
- Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (P4-ETS1-4)

##### Developing and Using Models

Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between

#### Disciplinary Core Ideas

##### PS4.A: Wave Properties

- The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. (P-PS4-1AR, P-PS4-2AR)
- The reflection, refraction, and transmission of waves at an interface between two media can be modeled on the basis of these properties. (P-PS4-3)
- Resonance is a phenomenon in which waves add up in phase in a structure, growing in amplitude due to energy input near the natural vibration frequency. Structures have particular frequencies at which they resonate. This phenomenon (e.g., waves in a stretched string, vibrating air in a pipe) is used in speech and in the design of all musical instruments. (P4-ETS1-4)

##### ETS1.B: Developing Possible Solutions

- Both physical models and computers can be used in various

#### Crosscutting Concepts

##### Patterns

- Empirical evidence is needed to identify patterns. (P-PS4-1AR, P-PS4-3AR)
- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (P-PS4-1AR, P-PS4-3AR)

##### Energy and Matter

- The total amount of energy and matter in closed systems is conserved. (P-PS4-1AR, P-PS4-3AR)
- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.

<p>systems and their components in the natural and designed worlds.</p> <ul style="list-style-type: none"> <li>Use a model to predict the relationships between systems or between components of a system. (P-PS4-2AR, P-PS4-3AR, P4-ETS1-4)</li> </ul> <hr/> <p><b>Connections to Nature of Science</b></p> <p><b>Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena</b></p> <ul style="list-style-type: none"> <li>A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. (P4-ETS1-4)</li> </ul>	<p>ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (P4-ETS1-4)</p>	<p>(P-PS4-1AR, P-PS4-3AR)</p> <ul style="list-style-type: none"> <li>Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems. (P-PS4-1AR, P-PS4-3AR)</li> </ul> <p><b>Structure and Function</b></p> <ul style="list-style-type: none"> <li>Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (P-PS4-2AR)</li> </ul> <hr/> <p><b>Connections to Engineering, Technology, and Applications of Science</b></p> <p><b>Interdependence of Science, Engineering, and Technology</b></p> <ul style="list-style-type: none"> <li>Science and engineering complement each other in the cycle known as research and development (R&amp;D). (P4-ETS1-4)</li> </ul> <p><b>Influence of Engineering, Technology, and Science on Society and the Natural World</b></p> <ul style="list-style-type: none"> <li>Modern civilization depends on major technological systems. (P4-ETS1-4)</li> </ul>
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<i>Connections to the Arkansas Disciplinary Literacy Standards:</i>		
<b>RST.9-10.7</b>	Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. (P-PS4-1AR)	
<b>RST.11-12.7</b>	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (P-PS4-1AR)	
<b>RST.11-12.8</b>	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (P4-ETS1-4)	
<i>Connections to the Arkansas English Language Arts Standards:</i>		
<b>SL.11-12.2</b>	Integrate multiple sources of information that is gained by means other than reading (e.g., texts read aloud; oral presentations of charts, graphs, diagrams; speeches) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data. (P4-ETS1-4)	
<b>SL.11-12.4</b>	Present information, findings, and supporting evidence, conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks. (P-PS4-1AR)	
<b>SL.11-12.5</b>	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (P-PS4-2AR)	
<i>Connections to the Arkansas Mathematics Standards:</i>		
<b>MP.2</b>	Reason abstractly and quantitatively. (P-PS4-1AR, P-PS4-2AR, P-PS4-3AR, P4-ETS1-4)	
<b>MP.4</b>	Model with mathematics. (P-PS4-1AR, P-PS4-2AR, P-PS4-3AR, P4-ETS1-4)	
<b>HSN.Q.A.1</b>	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (P-PS4-1AR, P-PS4-2AR, P-PS4-3AR, P4-ETS1-4)	
<b>HSN.Q.A.2</b>	Define appropriate quantities for the purpose of descriptive modeling. (P-PS4-1AR, P-PS4-2AR, P-PS4-3AR, P4-ETS1-4)	
<b>HSN.Q.A.3</b>	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (P-PS4-1AR, P-PS4-2AR, P-PS4-3AR, P4-ETS1-4)	
<b>HSA.CED.A.1</b>	Create equations and inequalities in one variable and use them to solve problems. (P-PS4-1AR)	
<b>HSA.CED.A.2</b>	Create equations in two or more variables to represent relationships between quantities; graph equations, in two variables, on a coordinate plane. (P-PS4-1AR)	
<b>HSA.CED.A.3</b>	Represent and interpret constraints by equations or inequalities, and by systems of equations and/or inequalities. (P-PS4-1AR)	
<b>HSG.MG.A.1</b>	Use geometric shapes, their measures, and their properties to describe objects. (P-PS4-2AR, P-PS4-3AR)	

## Physics

Topic 5: Electricity		
Students who demonstrate understanding can:		
P-PS2-4	Use mathematical representations of Newton’s Law of Gravitation and Coulomb’s Law to describe and predict the gravitational and electrostatic forces between objects. [AR Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of forces between static electric charges.]	
P-PS2-5	Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current. [AR Clarification Statement: Examples of investigations could be to create electromagnets and manipulate bar magnets through a coil of wire connected to an ammeter.]	
P-PS3-2	Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects). [AR Clarification Statement: Emphasis is on electric potential difference.]	
P-PS5-1AR	Use mathematical representations and conduct investigations to provide evidence of the relationships between power, current, voltage, and resistance. [Clarification Statement: Emphasis is on insulators and conductors accounting for Ohm’s Law, total resistance for combinations of resistors, and $P=IV$ .]	
P-PS5-2AR	Evaluate competing design solutions for construction and use of electrical consumer products.* [Clarification Statement: Examples could include efficiency of light bulbs (visible intensity vs. power) and thermal energy limits of wire.]	
P-PS5-3AR	Obtain and combine information on alternating and direct current circuits in various applications. [Clarification Statement: Examples could include why public utilities use AC while many devices use DC and energy loss in transmission of electricity.]	
P5-ETS1-1	Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. [AR Clarification Statement: Examples could include analysis of renewable energy systems for electricity generation and the effect of autonomous electric cars on the economy, society, and the environment.]	
The performance expectations above were developed using the following elements from the NRC document <i>A Framework for K-12 Science Education</i> :		
<div>Science and Engineering Practices</div> <div>Developing and Using Models</div> <div>Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s).</div> <div><ul style="list-style-type: none"><li>Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (P-PS3-2)</li></ul></div> <div>Constructing Explanations and Designing Solutions</div> <div>Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to</div>	<div>Disciplinary Core Ideas</div> <div>PS2.B: Types of Interactions</div> <div><ul style="list-style-type: none"><li>Newton’s law of universal gravitation and Coulomb’s law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (P-PS2-4)</li></ul></div> <div>PS3.A: Definitions of Energy</div> <div><ul style="list-style-type: none"><li>Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system’s total energy is conserved, even as, within the system, energy is continually transferred from one object to another</li></ul></div>	<div>Crosscutting Concepts</div> <div>Systems and System Models</div> <div><ul style="list-style-type: none"><li>When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (P-PS5-1AR, P-PS5-2AR )</li><li>Models (e.g., physical, mathematical, computer models)</li></ul></div>



<p>explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.</p> <ul style="list-style-type: none"> <li>▪ Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. (P-PS5-1AR, P5-ETS1-1)</li> <li>▪ Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (P-PS5-1AR, P5-ETS1-1)</li> <li>▪ Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (P-PS5-1AR, P-PS5-2AR, P5-ETS1-1)</li> </ul> <p><b>Using Mathematics and Computational Thinking</b></p> <p>Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.</p> <ul style="list-style-type: none"> <li>▪ Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (P-PS2-4, P-PS5-1AR)</li> </ul> <p><b>Planning and Carrying Out Investigations</b></p> <p>Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.</p> <ul style="list-style-type: none"> <li>▪ Plan and conduct an investigation individually and collaboratively to</li> </ul>	<p>and between its various possible forms. (P-PS5-1AR)</p> <p><b>PS3.B: Conservation of Energy and Energy Transfer</b></p> <ul style="list-style-type: none"> <li>▪ Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (P-PS2-5)</li> <li>▪ Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (P-PS2-5)</li> </ul> <p><b>PS3.C: Relationship Between Energy and Forces</b></p> <ul style="list-style-type: none"> <li>▪ When two objects interacting through a force field change relative position, the energy stored in the force field is changed. (P-PS3-2)</li> </ul> <p><b>PS3.D: Energy in Chemical Processes</b></p> <ul style="list-style-type: none"> <li>▪ All forms of electricity generation and transportation fuels have associated economic, social, and environmental costs and benefits, both short and long term. (P-PS5-2AR, P-PS5-3AR)</li> <li>▪ Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. Machines are judged as efficient or inefficient based on the amount of energy input needed to perform a particular useful task. Inefficient machines are those that produce more waste heat while performing a task and thus require more energy input. It is therefore important to design for high efficiency so as to reduce costs, waste materials, and many environmental impacts. (P-PS5-2AR, P-PS5-3AR)</li> </ul>	<p>can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (P-PS5-1AR, P-PS5-2AR)</p> <p><b>Cause and Effect</b></p> <ul style="list-style-type: none"> <li>▪ Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (P-PS2-4, P-PS2-5)</li> <li>▪ Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. (P-PS2-4, P-PS2-5)</li> </ul> <p><b>Scale, Proportion, and Quantity</b></p> <ul style="list-style-type: none"> <li>▪ Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth). (P-PS3-2)</li> </ul> <hr/> <p><b><i>Connections to Engineering, Technology, and Applications of Science</i></b></p> <p><b>Interdependence of Science, Engineering, and Technology</b></p>
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<p>produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (P-PS2-5, P-PS5-1AR)</p> <p><b>Obtaining, Evaluating, and Communicating Information</b></p> <p>Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs.</p> <ul style="list-style-type: none"> <li>Communicate scientific ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (P-PS5-3AR)</li> </ul> <hr/> <p><b>Connections to Nature of Science</b></p> <p><b>Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena</b></p> <ul style="list-style-type: none"> <li>Theories and laws provide explanations in science. (P-PS2-4)</li> <li>Laws are statements or descriptions of the relationships among observable phenomena. (P-PS2-4, P-PS5-1AR)</li> </ul>	<p><b>PS4.C: Information Technologies and Instrumentation</b></p> <ul style="list-style-type: none"> <li>Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, and scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. Knowledge of quantum physics enabled the development of semiconductors, computer chips, and lasers, all of which are now essential components of modern imaging, communications, and information technologies. (Boundary: Details of quantum physics are not formally taught at this grade level.) (P-PS5-3AR)</li> </ul> <p><b>ETS1.C: Optimizing the Design Solution</b></p> <ul style="list-style-type: none"> <li>Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (P5-ETS1-1)</li> </ul>	<ul style="list-style-type: none"> <li>Science and engineering complement each other in the cycle known as research and development (R&amp;D). Many R&amp;D projects may involve scientists, engineers, and others with wide ranges of expertise. (P-PS5-2AR, P5-ETS1-1)</li> </ul>
<p><i>Connections to the Arkansas Disciplinary Literacy Standards:</i></p> <p><b>RST.9-10.7</b> Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. (P-PS5-1AR)</p> <p><b>RST.11-12.1</b> Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (P5-ETS1-1)</p> <p><b>RST.11-12.7</b> Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (P-PS5-1AR)</p> <p><b>RST.11-12.8</b> Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (P-PS5-1AR, P5-ETS1-1)</p> <p><b>WHST.9-12.2</b> Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (P-PS2-5)</p> <p><b>WHST.9-12.7</b> Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate;</p>		

synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (P-PS2-5, P-PS5-2AR, P-PS5-3AR)

*Connections to the Arkansas English Language Arts Standards:*

**SL.11-12.5** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (P-PS3-2, P5-ETS1-1)

*Connections to the Arkansas Mathematics Standards:*

**MP.2** Reason abstractly and quantitatively. (P-PS2-4, P-PS3-2, P-PS5-1AR, P5-ETS1-1)

**MP.4** Model with mathematics. (P-PS2-4, P-PS3-2, P-PS5-1AR)

**HSN.Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (P-PS2-4, P-PS5-1AR)

**HSN.Q.A.2** Define appropriate quantities for the purpose of descriptive modeling. (P-PS2-4, P-PS5-1AR)

**HSN.Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (P-PS2-4, P-PS5-1AR)

**HSA.CED.A.1** Create equations and inequalities in one variable and use them to solve problems. (P-PS2-4, P-PS5-1AR)

**HSA.CED.A.2** Create equations in two or more variables to represent relationships between quantities; graph equations, in two variables, on a coordinate plane. (P-PS2-4, P-PS5-1AR)

**HSA.CED.A.4** Rearrange literal equations using the properties of equality. (P-PS2-4, P-PS5-1AR)

**HSS.IC.B.6** Read and explain, in context, the validity of data from outside reports by: identifying the variables as quantitative or categorical; describing how the data was collected; indicating any potential biases or flaws; identifying inferences the author of the report made from sample data. (P-PS5-2AR, P-PS5-3AR)



## Contributors

The following educators contributed to the development of this course:

Susan Allison – Benton School District	Rebecca Koelling – Highland School District
Katie Anderson – Little Rock School District	Karen Ladd – Nettleton School District
Dr. Katherine Auld - Northwest Arkansas Community College	Steven Long – Rogers School District
Dr. Daniel Barth - University of Arkansas at Fayetteville	Chris Lynch – Black River Technical College
Angela Bassham – Salem School District	Jacki Marlin – Perryville School District
Allison Belcher – Little Rock School District	Monica Meadows – Pulaski County Special School District
Debbie Bilyeu – Arkansas AIMS	Patti Meeks – Hamburg School District
Tami Blair – Texarkana School District	Melissa Miller – Farmington School District
Stephen Brodie – University of Arkansas at Fort Smith STEM Center	Jim Musser – Arkansas Tech University
Stephanie Brown – Quitman School District	Nanette Nichols – Wilbur D. Mills AR Education Cooperative
Cindy Bunch – Manila School District	Dennis Pevey – eSTEM Public Charter School
Cindy Cardwell – Bentonville School District	Tami Philyaw – Smackover – Norphlet School District
Larry Cooper – Springdale School District	Kathy Prislowsky – Stuttgart School District
Sarah Croswell – Virtual Arkansas	Kathy Prophet – Springdale School District
Tami Eggensperger – Cabot School District	Rhonda Riffin – Booneville School District
Shelley Forbess – El Dorado School District	Will Squires – Caddo Hills School District
Kyla Gentry – Searcy School District	Tim Trawick – Conway School District
Jenna Gill – Siloam Springs School District	David Wentz – Pea Ridge School District
Douglas Hammon – Little Rock School District	Andrew Williams – University of Arkansas at Monticello
Keith Harris – University of Arkansas at Little Rock Partnership for STEM Education	Wendi J.W. Williams – Northwest Arkansas Community College
Leonda Holthoff – Star City School District	Cathy Wissehr – University of Arkansas at Fayetteville
Amanda Jones – Poyen School District	Diedra Young – Ridgeway Christian High School, Pine Bluff